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Toward future-ready food packaging where materials meet AI

Kyushu University researchers propose a framework for packaging that senses, learns, and acts, moving from a passive barrier into an active, AI-powered tool against food waste

Fukuoka, Japan—Packaging already tells us where food comes from, when it was made, what's in it, and how many calories it contains. But researchers see a future where packaging can "see," in real time, what's happening inside and translate that into information that producers and consumers can act on.

Published July 13, 2026, in *Trends in Food Science & Technology*, a team from Kyushu University proposes a framework for "future-ready food packaging" built around a closed loop of recognition, judgment, actuation, and feedback. The paper brings together three research areas that have developed in isolation—intelligent sensing, self-healing materials, and AI-driven prediction—into a single, coherent system.

"Globally, roughly one-third of all food produced is wasted," says Fumihiko Tanaka, Professor at Kyushu University's Faculty of Agriculture. "It also carries a climate cost, as food loss accounts for roughly 8% of global greenhouse gas emissions, approaching the roughly 10% attributed to road transport."

Some waste happens when food gets crushed or torn during distribution. Another major source is unnecessary disposal. Much food is discarded before it actually spoils, driven by inventory turnover pressures or a printed date rather than the food's real condition. A clearer line between "starting to spoil" and "inedible" could prevent a meaningful share of that waste.

"Future‑ready packaging requires a different mindset," explains Fanze Meng, the paper's first author and a postdoctoral researcher at Kyushu University. "We wanted the film to communicate with the food itself, converting optical or gas signals into electrical data, and using AI to interpret what's happening inside."

From passive protection to active, real-time sensing

To move beyond packaging that merely delays spoilage, the team systematically reviewed recent advances. They linked previously scattered technologies into a loop of recognition, judgment, actuation, and feedback.

Recognition begins with the materials themselves. Sensors embedded in the packaging act like eyes, detecting the pH shifts, gases, and microbial byproducts that signal spoilage. Natural pigments such as anthocyanins, the compounds found in foods like purple sweet potatoes, are strong candidates for this role. They shift color as pH changes, offering a readable signal at every stage of spoilage. In spoiling meat, for instance, alkaline gases accumulate, and the material shifts continuously from purple-red to yellow-green.

“To survive real‑world distribution, the material needs more than just the ability to sense,” notes Xirui Yan, a JSPS researcher at Kyushu University. “Light and heat can cause false readings, and a bump or scratch can interrupt the signal, so reliability must be engineered in. One approach we’ve tried is anchoring the pigments with metal-organic frameworks and carbon quantum dots and adding self-healing capacity, so the film keeps working even after damage.”

Once the signal is transmitted, AI can take over. In the proposed system, the film converts optical and odor changes into electrical signals, which a connected device then reads and analyzes. The proposed system could then trigger a response, releasing antimicrobials to slow spoilage, sending alerts, or triggering logistical actions.

“It’s like giving produce a full check-up,” Yan offers a vivid comparison. “The film collects the signal, AI analyzes it, and together they tell you the food’s condition and what to do next.”

AI for the supply chain and the consumer

The team’s ambitions go beyond a single “smart” package. With AI, they envision a continuously updated recommendation system reflecting how differently foods spoil. Fruit, meat, and seafood spoil in different ways, and even different types of fish decay at different rates. By tracking the compounds each food releases as it spoils, the film captures unique patterns that AI can learn from. Over time, data collected by these sensors could help material designers and food producers adapt solutions to different foods.

“A deeper understanding of how produce deteriorates can also inform sales and consumption strategy,” Tanaka adds. Working with local governments and logistics partners, the team is exploring ways to grade produce by how well it withstands storage and transport. Short-shelf-life items would go to local markets, while hardier varieties are reserved for export, cutting losses by getting each item to the right place from the start. At the consumer end, the same intelligence could be delivered through a simple phone scan, getting instant, readable answers about the food’s condition.

Still, real-world hurdles remain. Long-term safety and stability assessments for food-contact materials—particularly certain nanomaterials—along with consistent quality control at industrial scale still require further research.

“We are setting a direction,” Meng and Yan conclude. “We hope others will build better ones on top of ours. If enough people move together, it becomes a beam of light, then a path—and eventually, that path could lead from the lab to something real.”

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For more information about this research, see “Toward Future-Ready Food Packaging: From Passive Protection to Intelligent, Self-Healing, and Data-Enabled Systems,”
Fanze Meng, Xirui Yan, Jiao Zeng, Amna Bibi, Xinrui Mao, Laras Putri Wigati, Tran Thi Van, Ata Aditya Wardana, Fumina Tanaka, Fumihiko Tanaka, *Trends in Food Science & Technology,* https://doi.org/10.1016/j.tifs.2026.105943

About Kyushu University
Founded in 1911, Kyushu University is one of Japan's leading research-oriented institutions of

higher education, consistently ranking as one of the top ten Japanese universities in the Times Higher Education World University Rankings and the QS World Rankings. Located in Fukuoka, on the island of Kyushu—the most southwestern of Japan's four main islands—Kyushu U sits in a coastal metropolis frequently ranked among the world's most livable cities and historically known as Japan's gateway to Asia. Its multiple campuses are home to around 19,000 students and 8,000 faculty and staff. Through its VISION 2030, Kyushu U will "drive social change with integrative knowledge." By fusing the spectrum of knowledge, from the humanities and arts to engineering and medical sciences, Kyushu U will strengthen its research in the key areas of decarbonization, medicine and health, and environment and food, to tackle society's most pressing issues.

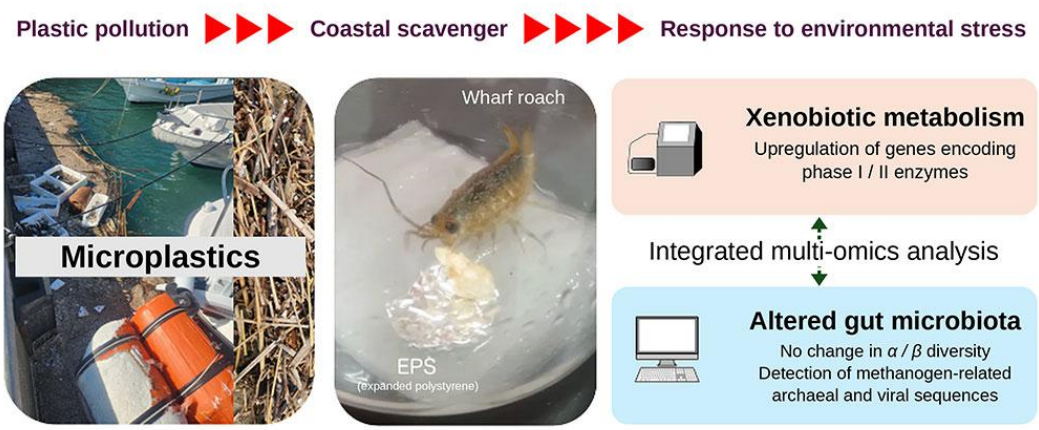

Fig. 1. Abstract of the research. Wharf roaches act as "cleanup crews" of the seashore. In recent years, microplastics, such as EPS, have been washing up on beaches and subsequently consumed by these creatures. A team from Kyushu University used multi-omics analysis to investigate what occurs in the digestive tracts of wharf roaches that have ingested EPS. The results revealed that roaches that ingested EPS had elevated activation of genes related to the metabolism of foreign substances. Additionally, while there were no changes in gut microbiota, they found methane-producing archaea and viruses only in EPS-consuming roaches.

Fig. 2. Wharf roach consuming EPS. A wharf roach consuming EPS during the team's experiments

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